

## **Historic, archived document**

Do not assume content reflects current scientific knowledge, policies, or practices.

# IRRIGATION OF GRAIN

BY

WALTER W. McLAUGHLIN

Irrigation Engineer



FARMERS' BULLETIN 863

UNITED STATES DEPARTMENT OF AGRICULTURE

---

Contribution from the Office of Public Roads and Rural Engineering

LOGAN WALLER PAGE, Director

Washington, D. C.

Originally issued, May 17, 1910 as No. 399; revised, August, 1917

Show this bulletin to a neighbor. Additional copies may be obtained free from the  
Division of Publications, United States Department of Agriculture

**M**ETHODS of irrigating grain crops are restricted somewhat because of the fact that such crops cover the entire surface of the plot on which they are grown. Objections to the flooding method, based on loss of water by evaporation, have less weight in the irrigation of grain than of other crops, grain fields seldom being irrigated after the seed is planted until the grain is high enough to protect the soil from sun and wind. Grain usually is the first crop grown on irrigated farms. For such farms flooding usually is better than other methods, since the preparation of the land for it is easier than for other methods.

Flooding from field ditches is the usual method of handling water in irrigating grain, but the border and basin methods are also adapted to such crops. These methods are described in detail in this bulletin, which also discusses the proper time to irrigate, the quantity of water required, and the cost of growing grain under irrigation.

# IRRIGATION OF GRAIN.

## CONTENTS.

	Page.		Page.
Methods of applying water-----	4	Relation of irrigation to rate of	
When to irrigate-----	15	seeding-----	21
Quantity of water required-----	19	Danger of failure-----	21
		Value of irrigated grain land-----	21

**A**S A RULE grains are the first crops grown on lands being brought under irrigation, for several reasons. They are food crops and therefore in demand; they require less outlay in preparing the land for irrigation and in seed, and bring quicker returns than most other crops; they do well on virgin soil and help to put the soil in condition for other crops; and in most sections their need for irrigation corresponds to the period of greatest water supply. Most of the streams of the arid region are torrential, having a flood period in spring and early summer, and low water in the late summer. The grains make their growth during this flood period, and are ready for harvest when the streams subside. They are therefore preeminently the new-land crops. As irrigated regions develop, special crops of high values are introduced, water is stored to meet their long-season demands, and the grains are displaced to a considerable extent.

In the regions which have been irrigated for many years, such as Colorado and Utah, grain is used in rotation with other irrigated crops. In the vicinity of Longmont, Colo., the prevailing rotation is alfalfa three years, potatoes or beets three years, wheat or barley two years, and seed back to alfalfa. In that section it is not considered good practice to have grain follow alfalfa, as it makes too heavy straw, while in Utah it is common practice to follow alfalfa with grain. Other rotations differ slightly, but this one may be considered typical. Grain is the least valuable crop in this scheme, and is given the least time.

Clearing and leveling land for the growing of grains under irrigation do not differ from clearing and leveling for other crops. The general subjects of clearing and leveling land are discussed at length

in other bulletins,<sup>1</sup> and that discussion will not be repeated here, but this bulletin will be confined to those practices which belong especially to the irrigation of grain.

### METHODS OF APPLYING WATER.

The fact that grain crops cover the entire surface restricts the methods which can be used for their irrigation. They must be irrigated by some form of flooding or in small furrows in which the grain can grow. In general, flooding is considered less desirable than other methods wherever any other method can be used, because the wetting of the entire surface increases the area exposed to evaporation, and causes soils of some types to puddle and bake when exposed to the sun and wind; but these objections to flooding have less weight with grain than with other crops, because it is seldom that grain fields are irrigated after the seed is planted until the grain is 6 or 8 inches high and protects the soil from sun and wind. From the standpoint of the settler, however, flooding is better than other methods, because it requires less preparation of the land for irrigation and the land is smoother for handling.

Probably the most common method of irrigating grain crops is flooding from field ditches, but they are also flooded in strips between levees, called the border method, and in basins formed by dividing a field by levees running both ways, and watered by furrows. These methods are described more in detail in the following pages.

### FLOODING FROM FIELD DITCHES.

Flooding from field ditches was the method adopted for irrigating grain in the sections of the arid region first settled, and it is still the prevailing method in those sections. It requires the least preparation of the fields and therefore appeals to the new settler. It can be used on quite rolling ground, since the field ditches can be run along the ridges and the water allowed to flow down the slopes in all directions. On the other hand, it requires more labor in applying water than any other method, and requires a larger stream of water than the furrow method, although one man can not use so large a stream as he can in either the border or check method. On steep land flooding is liable to cause cutting, and in cold, damp seasons flooding is said to aggravate trouble from rust.

The method consists in running small ditches through the fields and running the water from these ditches over the surface without other direction than is given to it by the irrigator with his shovel.

The direction of sowing if the drill is used is of importance where land is to be flooded. The miniature drill furrows can be

---

<sup>1</sup> U. S. Dept. Agr., Farmers' Bulls. 263, 373.

taken advantage of where they run with the slope to lead water quickly over the land in flooding, and when it is desirable to check the rate of flow upon the soils which have a rather steep slope or which do not absorb water readily, the drills can be run across the slope. This practice will be of considerable assistance to farmers who flood their land and is worth a trial. The cost of drilling will vary from 35 to 70 cents per acre. and will probably average 45 cents.

The proper location of the field ditches depends upon the lay of the land. On rolling land they will be run on the ridges, and the water will flow down the slopes. On land with a uniform slope, or a slope in one direction, they will be laid out in one direction and at regular intervals, the most common practice being to run a supply ditch down the slope along the margin of the field and from this run ditches through the field across the slope with just enough grade to carry the water. The water flows from the lower bank of each ditch down the slope to the next ditch (fig. 1). Another

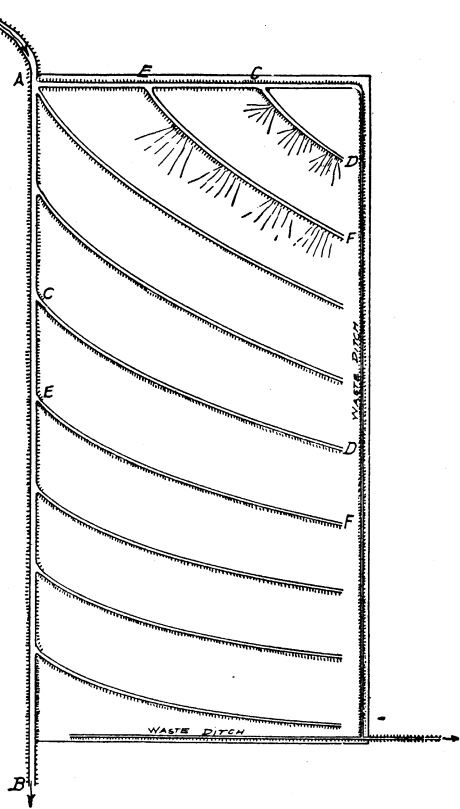


FIG. 1.—Flooding from field laterals.

arrangement is to run the supply ditch across the slope and from this run field ditches down the slope and turn water out of both sides, letting it run down the slope, as shown in figure 2.

On rolling land the proper location for the field ditches can be determined by eye, but on nearly level land it is necessary sometimes to have the lines run with some sort of a level, either some homemade device, such as a carpenter's level on a tripod or on a straightedge with a leg at each end, or a triangle with plumb bob, or with a regular surveyor's level. After cultivating a field for a few years, the farmer learns the slopes so thoroughly that he can run his ditches by eye without difficulty.

The grade given the ditches varies with the soil. It should not be steep enough to allow the water to cut out the bottom, and where ditches must be run down slopes, checks and drops should be put in rather than putting all the slope in the ditch. Where the field ditches are run across the slope they should be as nearly level as they can be and carry the water, in order that the water when checked up for that purpose may flow evenly over the ditch bank onto the land. The usual slopes are 1.5 to 6 inches per 100 feet, depending upon the class of soil. Heavy soils will permit of more slope or fall than lighter ones.

The field ditches running across the slope are placed at more or less regular intervals of 150 to 400 feet, according to the slope and the nature of the soil. On light, sandy soil they must be placed close

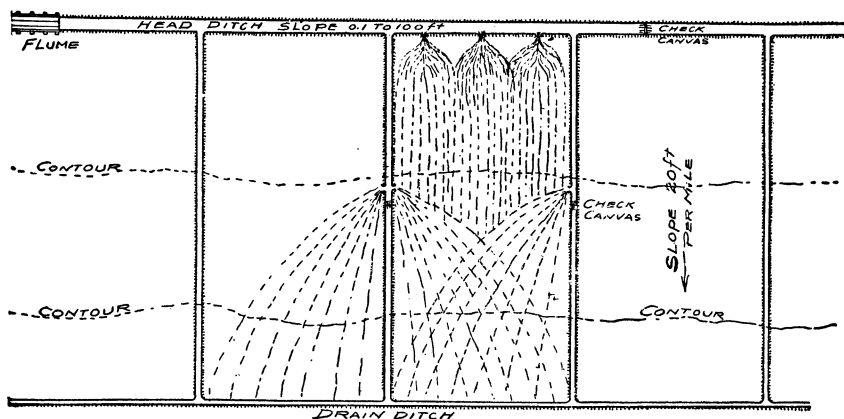


FIG. 2.—Flooding from head ditches in northern Colorado.

together, or the land near a ditch will get too much water before the land farther away has received enough, but on heavy soils the ditches may be placed farther apart, as the water soaks in more slowly. The general tendency is to place them too far apart, and this should be guarded against. The closer the ditches are spaced the more even the watering, but putting in more ditches than are necessary not only makes an unnecessary expense for construction, but withdraws the land occupied by the ditches from cultivation. The advantages and disadvantages of different spacings must be weighed in deciding upon it, but it is well to guard against trying to run water long distances from the ditches.

Some farmers use the same ditches as long as a field remains in grain, but it is more common to fill the ditches each year before harvest by turning the banks in with a plow or with an implement made for this purpose from disks (fig. 3). This makes it easy to run harvesting machinery over them and kills any weeds that may be grow-

ing on the banks. The location of the ditches can be seen closely enough for use another year if it is desired to use the same lines.

The first-mentioned method was formerly used almost exclusively in the grain and potato fields of eastern Idaho, but the farmers have long since discarded it, and now make new ditches every year. These can be made very cheaply with plow and V-crowder (fig. 4). Harvesting and spring plowing are done much more economically when the ditches are not in the way.

**Making field ditches.**—By field ditches is meant those which distribute the water over the fields, rather than the supply ditches which



FIG. 3.—Disks set for turning in field ditches.

bring the water to the fields. The location and construction of the permanent farm ditches are discussed in other bulletins<sup>1</sup> and will not be considered here. Field ditches are most commonly made with the ordinary plow and some sort of crowder (fig. 4), or with a double moldboard plow or lister. On land with considerable slope the ditches should run across the slope, and all the soil from a ditch should be thrown on the lower side. This can be done by putting additional wings on the plow to throw the soil farther out of the ditch and by running one side of the crowder flat against the upper side of the furrow and crowding all the earth in one direction. On

<sup>1</sup> U. S. Dept. Agr., Farmers' Bulls. 158, 263, 373.

nearly level land the excavated soil should be thrown on both sides. This is done by plowing out a dead furrow or by plowing a furrow with a double moldboard plow and clearing this out and smoothing the banks by hand with a shovel or by pushing the loose soil out with a crowder. The crowder is a V-shaped drag made of 2 by 12 inch

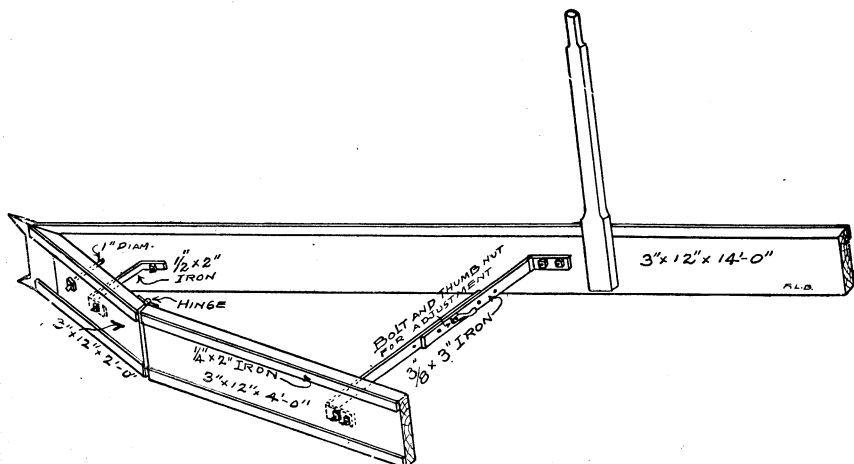


FIG. 4.—Adjustable "V" scraper or crowder.

planks, 10 or 12 feet long, steel shod, joined at one end and beveled to make a sharp cutting edge (fig. 4). The sides are hinged so that the width of the crowder is adjustable. Two to four furrows are plowed, and then the crowder is used to push the soil out. Ditches

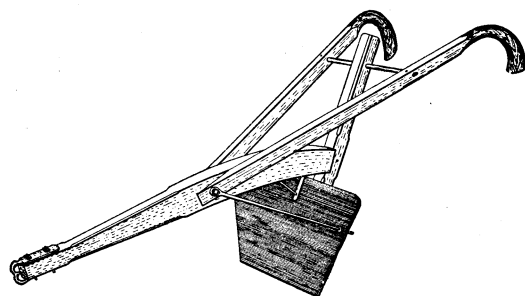


FIG. 5.—Dammer used in cleaning and damming field laterals.

are made 2 to 4 feet wide on top and 8 to 16 inches deep. They must be partly above the natural surface of the ground in order that the water may be run out over the surface. Dams are placed in the ditches to hold the water up and run it over the lower banks.

Usually twice through a ditch with the crowder will put it in good shape, and a man with a team can construct 1 to 1.5 miles of ditch in a day in a sandy loam soil.

Often dams for turning the water from field ditches are put in when the ditches are made. Sometimes they are made of earth scraped from the bottom of the ditch with a dammer (fig. 5) and dumped in piles at the desired intervals. Sometimes the earth is taken from the bottom of the ditch immediately below the dams and

when the dams are broken is washed back into the places from which it was taken. Manure is often used, being placed in piles in the ditch or alongside before irrigation begins. The canvas dam is, however, probably the most common form of dam used for turning water out of field ditches. It is inexpensive, easily made, and convenient to handle. It consists simply of a rectangular piece of canvas long enough to reach well across the ditch, with one edge fastened to a timber or pole, which is placed across the ditch. As a rule, there are no permanent structures in the field ditches in grain fields irrigated by flooding. Gates are sometimes put in the supply ditches, but often the water is held up in the supply ditch by temporary dams and turned out through cuts in the ditch bank. Water is run in one or more of the field ditches at a time, depending upon the size of the stream delivered to the irrigator. The usual stream run in a ditch is about 1 second-foot, or 40 to 50 inches. If water is delivered in a stream of 2 or 3 second-feet this stream should be divided among as many field ditches. If the land is in good shape, one man can look after two or three ditches, and to make the best use of his time he should have as large a stream as he can handle. This should be kept in mind in making agreements for water, and where the farmer's water right does not call for as large a stream as he can handle, arrangements for rotation with his neighbors should be made, in order that each may have a good working stream.

Water is turned into one or more ditches and allowed to flow down to the first dam, where it is held up and made to overflow the lower bank of the ditch and flow over the field to the next ditch. When this section has received enough water the dam is broken and the stream flows down to the next dam, and the operation is repeated until the whole field is covered. With as large a stream as they can handle two men can water 10 to 25 acres in a day of 24 hours in 12-hour shifts.

#### FLOODING BETWEEN BORDERS.

A modification of the flooding method just described is flooding between levees or borders. This requires more preparation of the land before irrigating than does flooding from field ditches, but requires less labor in applying the water. A head ditch or supply ditch is run across the upper end of the field, running across the greatest slope. From this head ditch parallel levees or borders are run down the slope at intervals of 40 to 60 feet, dividing the field into a series of lands (fig. 6). Each land is made level between the borders, so that water can be made to flow down the slope in a sheet extending across the land from border to border. If the field is properly prepared the water requires no attention from the irrigator

after he has turned it into a border until that part of the field has received enough water, when it must be shut off.

If the field is a long one a supply ditch runs down the slope and from this head ditches are run across the lands at intervals (fig. 6). The distance which water can be run down a land between head ditches depends upon the character of the soil. If the soil is very light the lands must be short or the upper ends will get too much water; if the soil is heavy they may be longer. Lands vary in length from 500 to 1,000 feet and even more in some sections.

The borders dividing the lands may be more or less permanent. In some places they are mere back furrows, while in other places

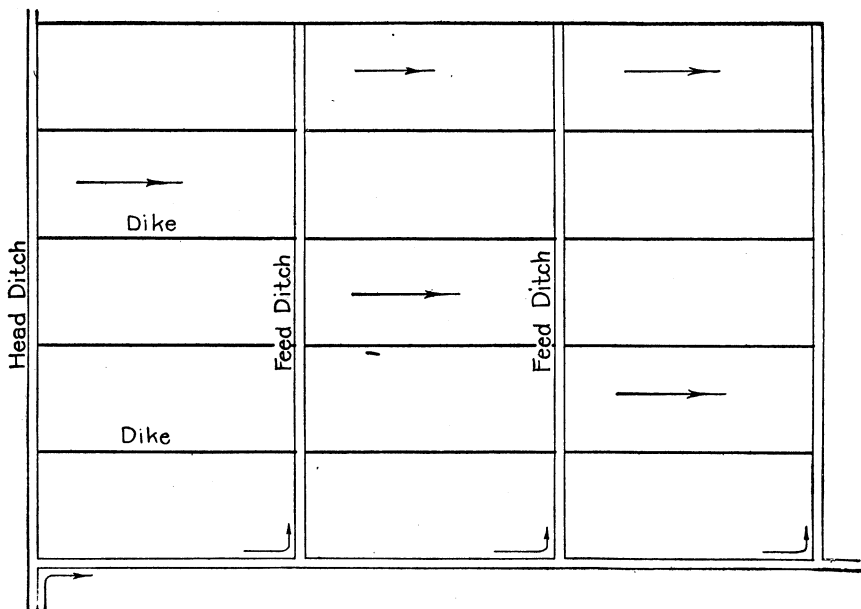


FIG. 6.—Layout of field for flooding between borders.

they are permanent embankments. They may be made by plowing several furrows and crowding the loose soil into a ridge with a ridger (fig. 7), or they may be made with a scraper. In some sections they are made when the land is being leveled. A scraper is drawn across the slope, taking soil from the high points and dumping it in the levees. These are afterwards smoothed down with a drag. They are made broad and low, so that the crop can be planted all over them and machinery can be run over them without difficulty.

The head ditches are larger than the field ditches used in flooding, as larger streams are used. A man should have a stream of at least 2 or 3 cubic feet per second and can handle one twice as large, as he has to give little attention to the water except to turn it into the

lands. The ditches are usually permanent, with gates where the water is turned into the lands.

This method is adapted to both light and heavy soils. If the soil is light a large stream can be forced over the surface quickly before it has time to soak in too deep, and if the soil is heavy a smaller stream may be used and be kept running for a long enough time to allow it to soak in sufficiently. As the irrigator does not have to watch the water, this slower process is not a great drawback.

Care should be exercised to adapt the size of the stream turned into any strip to the character of the soil, the slope, and the stage of the crop, so as to secure a proper wetting of the soil without loss by deep percolation. Care is necessary also to prevent loss of water by waste at the lower ends of fields. The farmer should watch the water and learn by experience when to turn it off so that it will just reach the end of his field.

This system is used to a considerable extent in the Southwest, but is not generally used elsewhere. It is becoming more popular on account of the saving of labor in applying water.

#### FLOODING IN CHECKS.

For flooding in checks a field is divided into a series of basins by levees running across the field in both directions. The checks are sometimes made rectangular, and sometimes the levees running across the slope are run on contours. The rectangular checks are adapted to land which is nearly level or has a uniform slope, so that contour lines would be nearly straight. Rectangular checks are better than contours where they can be used, because they conform to field lines and present less obstruction to the operation of farm machinery.

The distance between the levees running across the slope of the field is governed principally by the slope. The fall between two levees must be less than the height of the levees, so that

water will be held high enough to cover the surface completely. Levees must not be too high to be crossed by harvesting machinery, and consequently on land of considerable slope they must be placed close together. For this reason this system can not be used on land

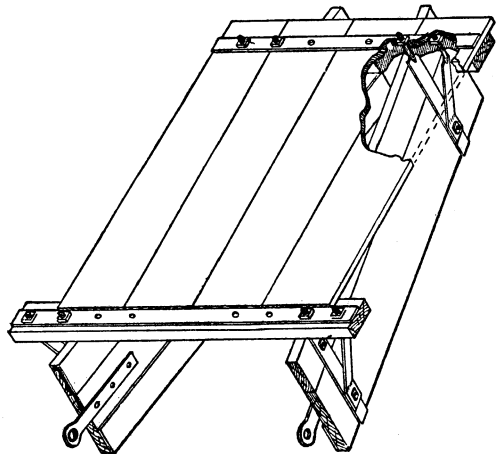


FIG. 7.—Adjustable ridger.

which has much slope, as the levees would be too close together to be practicable.

The size of the checks is also governed to some extent by the slope, but to a considerable extent by the nature of the soil and the size of the head of water available. While large checks are used in places, the tendency is to make them smaller, the usual sizes being 1 to 2 acres in a check.

When the small checks are used on nearly level land the lines for the levees need not be run with an instrument, as the slope in the distance between levees is not enough to make their exact location important. On more sloping ground it will be necessary to determine the levels on the field and locate the levees with reference to these.

Broad, low levees over which machinery can be run are best. The crop is seeded all over them, and usually the levees will receive enough water to mature the crop. The levees are built as described for the border method. The attempt is made to make a uniform slope within each check, and the earth is taken from the high places to form the levees.

In some sections the supply ditch is run across the upper end of the field and water is turned from this ditch into the upper check of each series and run from that one through a gate or cut in the lower levee into the checks below in turn, the usual practice being to fill the highest one first and use the lowest one to catch the waste from the others. Sometimes, however, the lowest one is filled first and those above in turn. Another system is to make supply ditches on alternate levees running down the slope and fill the checks on both sides from these ditches. If the slope is too great to run water in this way without washing, drops should be put in the ditches. Combined gates and drops can be used to good advantage. This system, while it necessitates the building of more ditches, permits a more uniform distribution of water and is therefore better. The upper checks should be filled first, as in this way any water finding its way over or through the levees will be caught on the dry checks below.

The preparation of land for irrigation by this method is more expensive than for other flooding methods previously described because of the additional levees required. However, the labor of applying water is less than with flooding from field ditches, since it is necessary only to turn the water into the checks and the levees will hold it up, so that the entire surface will be covered. This method is adapted either to light or heavy soils. With light, open soils a large head of water can be turned into a check and forced over it before it has time to soak away near the gate where it is turned in, while with heavy soils it is possible to hold the water on the surface until a sufficient quantity has been absorbed. With this method one

man can handle a stream of 5 to 10 second-feet, making it possible to cover his land in a short time. Before preparing his land for flooding in checks the owner should make sure that a large stream of water will be available, as this method is not adapted to the use of small streams.

#### FURROW OR CORRUGATION IRRIGATION.

The soils in the irrigated section of the Northwestern States are largely of volcanic origin, and puddle when wet and bake and crust when exposed to the sun and wind. For that reason crops are seldom flooded. The common method of irrigating grain and alfalfa is by what is called locally the corrugation method. In this method the water is run in small, shallow furrows, from which it percolates laterally through the soil, but does not run over the surface. A small stream is run for a considerable time in each furrow until the adjacent soil has received enough water. It is adapted to heavy soils, which take water slowly, and to considerable slopes, since the furrows can be run across the slopes at any angle which gives the grade required for the desired velocity of water. Although this method is adapted to heavy soils, it is not adapted, generally speaking, to the sedimentary soils of the Southwest, where the slopes are rather flat. It is adapted to the use of small streams of water, since water can be run in few or many furrows, according to the size of the stream available.

Feed ditches are run across the slope of the field, while the furrows run down the slope or across it at an angle, according to the steepness of the slope. The ditches should be nearly level, so that when water is held up by the dam it will flow over the lower bank throughout a considerable length of the ditch. In the Twin Falls country in Idaho check boxes are put into the feed ditches, so that water can be held on a series of levels.<sup>1</sup> The check boxes are supplied with flashboards, which hold the water up to any desired height and allow the surplus water to flow over and down the ditch to the next check box. The water is turned out to the furrows through lath boxes placed in the lower bank of the ditch for that purpose. The boxes in the section of a ditch between two check boxes are on a level above the surface of the water when unchecked, but at such a height that when water is held up by flashboards in the check box they will be submerged slightly and will discharge water to the furrows. The boxes increase the cost of preparing the land for irrigation, but decrease the labor required in applying water, and their use makes possible a very even distribution of water. As water is allowed to run in one set of furrows for several hours this system is especially valuable where

---

<sup>1</sup> See U. S. Dept. Agr., Farmers' Bul 373, rev.

night irrigation is practiced. Water can be turned into a set of furrows and needs no further attention for some time.

In other sections water is turned out through cuts in the lower bank of the ditch and divided among the furrows by the irrigator with his shovel. This requires constant attention by the irrigator, which is not necessary when the lath boxes are used. In some cases the supply ditch is cut and the water turned directly into the furrows, but in a majority of instances where there is a liability of the soil washing it is the practice to use a distributing ditch in addition to a supply ditch. This distributing ditch is rather shallow, having a width of 1 to 3 feet, and is run below and parallel to the head ditch some 3 to 6 feet distant. The water is turned from the supply ditch into the distributing ditch and from the distributing ditch into the furrows. The advantage of the distributing ditch is found in that if one section of the distributing ditch washes out the water can be readily turned out of this section and used elsewhere until the places washed out have been repaired. It is not common to use the double ditch except at the top of a field.

In Idaho and Washington the furrows are usually made with a furrowing sled, which consists of two or three runners made of logs or 6 by 6 inch timbers, spaced at whatever distance is desired between the furrows, and sharpened at the front end. These will make furrows 3 to 5 inches deep. In grain fields the furrows are made 1.5 to 3 feet apart, depending upon the character of the soil. In Utah furrows are made sometimes with a roller having raised rings on its surface. When the roller is drawn over a field these rings make the furrows and crush the clods, which aids in the even distribution of the water.

The length of furrows is 150 to 600 feet, according to the slope of the land and the nature of the soil. Feed ditches are run across the field at these intervals and take up the waste water from the furrows above them and supply water to those below. The furrows are made just after seeding, so that the crop covers the entire surface.

Preparing a field for irrigation by this method is more expensive than for flooding, but less labor is required for putting on the water. It secures a more even distribution of water, since the furrows, if the field is prepared properly, will carry the water to every point in the field.

This system is not adapted to very open soils, since in them the water will percolate down beyond the reach of plant roots, rather than to the sides, moistening the soil between furrows. It is especially valuable on clay soils, which bake and crack after being wet.

**WHEN TO IRRIGATE.**

The character of the soil and subsoil has a large influence upon the time of irrigating. A heavy soil with tight subsoil will receive large quantities of moisture and hold it for a long time, making it possible to irrigate heavily and at long intervals. If such a soil is underlain with gravel the water will drain out and more frequent irrigation will be necessary. The same principle holds with lighter soils. The lighter the soils and the more open the subsoils the more frequently it will be necessary to irrigate. The lighter soils have less water capacity, so that the irrigations should be light and frequent.

The ideal condition is to have sufficient moisture in the soil at the time of seeding to germinate the seed and keep the plants growing until they are large enough to shade the ground when the crop is irrigated. It is irrigated again when the grain is in the boot—that is, when the heads are just beginning to show—and sometimes again when the heads are filling.

In localities having a small winter precipitation or where the evaporation is excessive during the winter months, as is the case along part of the Pacific coast, in New Mexico, Arizona, and a few other localities, the utility of irrigation during the nongrowing season has been demonstrated. Where the water supply is deficient, irrigation at a time when the water can be obtained, either in the winter or the spring before planting, is of service to store moisture in the soil for the plant's use later in the season. Winter irrigation is not well understood or its benefits realized as would be the case were the practice more extensive. Irrigation prior to planting is of great service in localities with a limited water supply where such supply is required by other and more profitable crops later in the season.

In winter irrigation the land is irrigated once or twice before heavy freezing weather, the first irrigation two weeks to a month prior to the last one, which should occur just before heavy frost. The better method of winter irrigating is by the furrow method, unless the land can be harrowed after the last irrigation, as a mulched surface during the winter is desired, that the winter precipitation may enter the soil readily. Sufficient water should be applied to saturate the soil to a depth of 4 to 6 feet, provided the soil is rather deep and not underlain near the surface with porous material such as sand and gravel. Some difficulty is experienced upon the heavy lands in irrigating in the spring prior to planting, as the soil dries out very slowly and the grain can not be planted until late. Better results are obtained in such cases by watering just after the crop has been planted. The furrow method is to be preferred upon medium to heavy soils if irrigation is required at any time before the plants have

attained sufficient growth to shade the ground. In case water is applied in the spring before planting, the land should be plowed, harrowed, furrowed, and irrigated. The irrigation should be followed as soon as possible by the disk harrow and the float, then by seeding. If the land has been plowed the previous fall, the disk harrow should take the place of the plow. Furrowing should follow planting for the purpose of subsequent irrigations. If the land is not to be irrigated until after the grain is planted, the land should be plowed, if not plowed the fall previous, double disked, harrowed, floated, planted, and furrowed, in the order named. In case the ground is cloddy, the roller may be used either before or after the disk.

Late summer or early fall irrigation is proving very satisfactory for destroying weeds upon foul land. When an early maturing crop like grain is grown, the land is irrigated immediately after the grain is harvested, to supply moisture with which to germinate weed or other seeds that may be in the soil. The land is plowed later in the fall and the weeds turned under; the plowing is followed later by disking and again irrigating if fall irrigation is practiced. This method of weed control is to be commended, as it not only rids the land of weeds but affords considerable green manure.

In the Rocky Mountain States usually enough rain falls in the spring to start the grain and keep it growing until it is 6 or 8 inches high. If not, it is better to irrigate before planting rather than after. The land should be irrigated long enough before planting to allow of thorough cultivation before seeding, in order to put the soil in proper tilth. Where spring rains are common it is sometimes possible to irrigate in the fall or winter, and in this way store sufficient water in the soil to start the grain crop, or even bring it well along toward maturity. This can be done only on deep retentive soils. On shallow, light soils, or those with free underdrainage, it is not possible to retain much moisture throughout the winter. Irrigation before planting is not always advisable, on account of delaying planting while the soil is drying out sufficiently to work well. It may then be necessary to irrigate just after planting. The danger in this is that the soil will bake and crust so that the young plants can not force their way through. If such a crust forms, it may be necessary to irrigate again to soften the crust and let the plants through, or the crust may be broken with a corrugated roller or with a peg-tooth harrow with the teeth sloping well back. The plants should be kept growing all the time and not allowed to suffer much for want of moisture. A crop which suffers for moisture or for any other reason has its vitality impaired by that much, and it is hard to restore lost vitality.

It is desirable in growing a crop for grain rather than for straw that the straw be rather short and not too rank. This is desirable for several reasons, chief of which is that it is not often possible to produce a heavy growth of fodder and of grain upon the same plant; the ranker the straw the more liability to lodging, to rust and other diseases, and usually the grain is softer and poorer in quality. Where the straw is not of importance, the first irrigation should be delayed as late as possible without impairing the vitality of the plant. The less water used in growing grain, the greater the percentage of gluten in the seed and the higher the food value. It is a good practice to withhold the first irrigation somewhat in order to obtain early ripening and a good quality of grain. There is danger of impairing the vitality, however, unless great care is taken and sound judgment used in determining when the grain begins to suffer for moisture. Grain sometimes starts a second growth if the first irrigation is left too long, and this second growth is fatal to a profitable yield. The grain plant obtains from the soil a great part of its total weight during early growth. During the intermediate growth the plant is undergoing certain changes preparatory to building up the seed. During the later growth the seed is being made chiefly from material stored in the stalk. More moisture is required during the early and later growth for these purposes than is required during the intermediate growth, and it is better to let the grain suffer a little during the early growth than during the later growth if water is not available at both times. Moisture must be present to flush the material from the stalk into the head or the grain will be shrunken, and the longer the stalk the more water will be required for this purpose. Early lack of moisture means a shorter straw, but not necessarily a small yield of grain, while a lack of moisture in the later growth means a shrunken grain with a comparatively large yield of straw. It is almost always a good rule to furnish some moisture by irrigation when the grain is in early milk to insure the flushing of the stalk. It is not good practice to irrigate grain in the final stage of its growth.

Many natural and artificial conditions influence the time and amount of irrigation, and it is the farmer who best understands and makes use of them who is the most successful. The condition of the soil, together with the appearance of the plant, affords a practical index of the requirement of the plant for water. Soil taken from a few inches below the surface should retain its shape after having been squeezed in the hand. This test is of great value after a little practice, but frequently the inexperienced will be deceived by the heavier clay soils, as they may retain their shape and yet have very little moisture that can be obtained by the plant. An experienced farmer

follows the rule upon loams not to irrigate until the soil, which has been squeezed in the hand as indicated above, appears barely to hold together. This test will be too close for the inexperienced.

The appearance of the plant is an excellent indication of the moisture condition where no considerable quantity of alkali is present. However, the appearance of grain when troubled with alkali, in the early stages, is somewhat similar to the appearance of grain suffering from lack of moisture. Grain which has plenty of moisture is of a light-green color, and when it begins to suffer for water it turns to a darker green and the lower leaves begin to fire or turn yellow. When this condition appears water should be applied. However, it is best to anticipate this period a little, as the grain does not show its lack of moisture until some damage has been done.

If the first irrigation of grain, or the second in case it was necessary to irrigate to start the seed, occurred when the grain was in the early boot, it should be followed by an irrigation when the grain is in the late flower, and a last irrigation when the grain is in the late milk or early dough. It is not frequent that four irrigations are required if the first occurs when the grain is in the boot. However, in the localities subject to hot winds and excessive evaporation, a fourth irrigation may be necessary. Much depends upon the depth and retentiveness of the soil, but if the grain does not require irrigation until it is in late flower, there will probably be but two irrigations, the second occurring when the grain is in medium milk. Better results will usually follow three irrigations than two, although no more water is needed for the three irrigations than for the two.

The time of application will have as much and frequently more influence than the number of irrigations upon the yield and quality of grain. In the above outline of irrigations it is presumed that the spring precipitation and the moisture stored in the soil will provide for the grain until it reaches the booting stage. If irrigation water is applied immediately after planting, three irrigations will probably follow at the time indicated above.

The irrigation of grain which is rank at a late date makes the grain liable to lodge. The water softens the stalk at or near the surface of the ground, the stalk is top heavy, and a moderate or hard wind will cause the grain to topple over. This is a serious matter in windy localities, and as a result the last irrigation should not occur too late in growth. A damp growing period or too frequent irrigation tends to produce an inferior grain and to promote rust.

In growing grain for fodder, more applications of water will be given during the early growth, as the object is to secure a rank growth of straw, and the fodder is cut when the grain is in the milk. The number of irrigations for this purpose varies from 1 in the colder climates to 12 or 15 in the hot, dry climate of Arizona.

## QUANTITY OF WATER REQUIRED.

The quantity of water to be applied at each irrigation depends upon the number of irrigations, depth of soil, nature of subsoil, the purpose for which the grain is grown, the condition of the crop, climatic conditions, and, from a practical standpoint, the length between water turns, the available supply, method of application, the requirements of other crops, the expertness of the irrigator, and the length of time the field has been under irrigation and cultivation.

The amount of water applied to the crop for the first irrigation varies greatly. As a general rule, the soil is driest at the time of the first irrigation, and more water will be required to irrigate properly at this time than subsequently. It is always safe to assume that the ranker the growth of straw the greater will be the quantity of water required at the time the head is making. Water for irrigation is always plentiful during the early spring, but at the time the grain is filling the supply usually begins to fail. The usual practice of the farmer is to irrigate heavily in the spring and use less water as the season advances. It has been observed often that better yields have been obtained by the farmer using the least amount of water for the first irrigation when the water supply was limited for the second and third irrigations. However, if the first irrigation comes at a time when the grain is in the milk then it should be heaviest. When the first irrigation comes about the time of booting, the heavier irrigation should occur, if at all, at the second irrigation or when the grain is in the milk. On light, well-drained soils underlaid with gravel the farmer frequently applies 1 to 2 feet at each irrigation, while on the heavier and more poorly drained soils he may not be able to apply more than 4 to 6 inches. For economy of water these amounts might better be reversed, as the heavier soil will retain a large part of the water applied, while much of the water applied to the sandier soil will be lost by deep percolation. An average application for the first time will be 8 to 10 inches; at the second application 2 inches less will be the average. The third irrigation, which will occur when the water is scarce and in demand for other crops, will be lighter than either the first or second. The best result will be obtained usually with three irrigations, giving approximately 7 to 8 inches for the first and 6 inches for each of the last two irrigations. These amounts represent the water applied to the crop in the field and do not cover the loss from seepage and evaporation. The total depth of water applied to the grain crop upon the older lands will vary from 1 to 4 feet. The larger amount is used upon the more porous lands and in the warmer climates. An average depth of 1.5 feet will about represent the amount applied to the crop in the cooler climates and 3 feet in the warmer climates. However, in some sections, as the Imperial

Valley, Cal., only about 1.5 feet in depth is applied to barley. This does not include the water lost before it reaches the farm. The losses in canals and laterals will average from 1 to 3 per cent per mile, while in gravel and loose material the losses are frequently 10 to 20 per cent per mile. These losses, together with the losses from the distributing ditches and through carelessness of the irrigator, will average at least 50 per cent. Where there are two or more canals paralleling one another and on the same side of a valley, with an uninterrupted slope between them, there may be a gain shown by the lower canal or canals through catching the seepage and waste irrigation water from above.

The amount of water required by new land is usually more than that required by older land. Very few data are available from which to judge the requirements of new land for water, but it is usual to assume that during the first two or three years 50 to 75 per cent more is required than for old land, and 20 to 25 per cent for the following two years.

The Bear River Canal in Utah affords an excellent illustration of the relative requirements of new and old lands for water. During the first few years of irrigation in this valley a second-foot of water was used upon 60 to 80 acres, and apparently the land required that amount. During the past 3 years, or 17 to 20 years after the settlement of this valley, the amount of land actually served by a second-foot of water averaged for all crops 116 acres and for the grain crops 163 acres. This represents all the water the farmer actually desired to apply, as the canal company was under contract to supply a second-foot for each 80 acres. This decrease in the use of water is the result of more careful farming, a better understanding of the water requirements of the crops, a better tilth of the soil, and largely of the gradual rise of the ground-water level. Where the ground-water level was 15 to 30 feet below the surface in 1890 it can now be found within 3 to 8 feet of the surface, indicating wasteful use. Drains are being installed to relieve this land of the surplus water.

What is true of the Bear River Valley is more or less true of all the older irrigated valleys. The experience has been that the ground water gradually rises with continued irrigation. The water level will be highest in the latter part of the irrigation season and in the late fall, gradually subsiding after irrigation has ceased for the season until irrigation begins the following season. In many localities the lower lands have been completely waterlogged and made worthless unless they are drained, as a result of wasteful application of water, together with seepage from canals and ditches.

The amount of water required at the source of supply under average conditions will vary with several factors, as indicated before. If

it is assumed that the grain requires 1.5 to 3 acre-feet and this amount represents but half of the water turned into the canal, the quantity of water required at the source of supply will average 3 to 6 acre-feet per acre. This corresponds very closely to the amount found in practice. For new lands during the first few years it will be found that 50 per cent more than the above estimate may be necessary, while frequently in older sections 2 to 5 feet would be ample.

### **RELATION OF IRRIGATION TO RATE OF SEEDING.**

In raising grain, both under irrigation and without irrigation, it has been found that the best rate of seeding depends upon the available supply of water. If there is plenty of water land should be seeded heavily, but if the water is scarce the seeding should be lighter. Experiments in Utah have demonstrated that 1 bushel of wheat to the acre is sufficient when only a moderate supply of water is used, and that when water is scarce three-fourths of a bushel of seed per acre will give larger returns than heavier seeding.

### **DANGER OF FAILURE.**

The danger of partial failure under irrigation may be summarized as follows: The application of too much water, resulting in drowning the grain or delaying the ripening too late; the application of too little water, resulting in a shrunken grain; the application of large amounts of water at the wrong time, or the application of too light an irrigation during the filling stage. Upon heavy soils the grain may be burned or the ground may bake so hard that the grain is choked. In an area containing much alkali the alkali may be brought to the surface in large quantities and the crop destroyed, the land becoming foul to the detriment of the grain. Unfavorable meteorological conditions, such as wind, rain, hail, and frost, may cause serious injury.

### **VALUE OF IRRIGATED GRAIN LAND.**

In the larger part of the irrigated section the water has a greater value than the land, on account of there being plenty of land and a very limited water supply. The value of water and of land is very hard to determine separately. The value of improved lands and especially land devoted and planted to intensive and highly profitable crops, such as orchards, is often spoken of, yet were this land deprived of its water right it might be valueless.

The price of good grain land, including water, not suitable for beets, orchards, or other similar crops, varies from \$50 to \$100 per acre. Land that is adapted to more profitable crops and favorably

located with regard to transportation facilities has a value of \$150 to \$500 per acre, including water rights. In a new locality the land values would be much lower than in the older sections. Including all classes of land, it is safe to assume that the average price of land upon which grain is grown by irrigation, including the water rights, will approximate \$100 per acre. Very little grain is grown upon the land of higher value or with high-priced water rights, except in rotation with other crops.

Grain is essentially a crop for the farmer with a very limited capital or for the farmer on new land. It is not advisable, however, to grow many crops of grain in succession on new land, as the yields fall off rapidly. The land should be seeded to alfalfa and grain used only in rotation after the first year or two. It is not a crop for revenue upon small farms or where intensive farming is practiced.

